Mechanical Pumped Cooling Loop for Spacecraft Thermal Control:

Pradeep Bhandari, Gaj Birur and Marsh Gram
Thermal and Fluids Systems Engineering Group
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

Spacecraft thermal control design is traditionally based on passive elements that help in maintaining the spacecraft temperatures within the required limits. The passive thermal hardware include various types of surface finishes and paints, multilayer insulation, thermostatically controlled heaters (both mechanical and electronic thermostats), radiators, mechanical louvers, and conduction control elements. Heat pipes have been used increasingly in the last fifteen years to both enhance and control heat transfer between spacecraft components. Capillary pumped loops also have been used in recent years to overcome some of the limitations posed by the heat pipes.

Mechanically pumped single-phase cooling loops have been used extensively for ground applications and aircraft applications. They have also been used in spat.c for short duration applications (a few weeks) such as in the space shuttle. Mechanically pumped single phase cooling loops can provide enormous flexibility and robustness to the thermal design of spacecraft. They eliminate some of the limitations posed by heat pipes or capillary pumped loops in relation to integration and testing of the spacecraft. With the inclusion of variable control elements in the loop, they can provide some autonomy for the spacecraft thermal control that would greatly reduce monitoring efforts needed during flight. However, mechanically pumped loops have not been used for long duration space applications lasting months or longer. The main reason for this has been the lack of heritage of the mechanical pumps on long duration missions. Even short-term spacecraft flights (lasting less than year, such as Clementine) have used complex combinations of various kinds of heat pipes to achieve the thermal control required.

Currently, a mechanically pumped loop is being designed and fabricated as a part of the thermal control system for usc on the Mars Pathfinder spacecraft which will be launched in December 1996. The flight duration requirement for the loop is about seven months. The pumped loop design was chosen as the most cost effective design to accommodate the difficult spacecraft integration, test, and flight requirements. Redundant motor/pump units arc used as part of the design. The only variable control element used in the loop is a thermal control valve which modulates the flow as a function of the fluid temperature.

Heat pipes, thermal/mechanical links were traded-off with pumped loop systems before the select ion of the mechanically pumped loop concept for the Pathfinder Spacecr aft, Tradeoffs associated with the selection of the working fluid (Freon-11), tubing (size & layout), schemes to vent the freon before Martian entry, and ground support cooling were performed, A development test to characterize the thermal and hydraulic performance of the cooling loop was conducted, Life testing of the long-term performance of this loop is ongoing. This presentation will discuss the design of this cooling loop, the trade-offs performed, some details of the associated hardware and results of tests conducted to characterize its performance.